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Electronic Sputtering Effects in TOF-SIMS Studies using Slow Very Highly Charged Primary Ions like Xe^{44+} and Th^{70+}

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The development of new ion source technologies, such as the Lawrence Livermore National Laboratory Electron Beam Ion Trap (EBIT) [1], has made low emittance ($\leq 1\ \pi$ mm mrad) beams of slow ($v \ll v_{Bohr} = 2.2 * 10^6$ m/s) very highly charged ions (like Xe^{44+}, and in principal up to U^{92+}) available for ion solid interaction studies [2]. The prominent feature in these interactions as compared to the interaction of singly or modestly charged ions with solids is the dominance of electronic over collisional effects. While the highly charged ion approaches a surface, up to several hundred electrons are emitted from an area of only a few square nanometers [3]. This drastic disturbance of the local charge equilibrium results in very effective electronic desorption of surface adsorbates. E. g. positive secondary hydrogen ion yields from thermal SiO_2 films are found to increase almost with the fifth power of the incident ion charge: $Y_{H+} \sim q^{4.8}$. The lattice of insulators and modest conductors relaxes in a "Coulomb Explosion" [4] before charge neutrality can be reestablished. Resulting secondary ion yields show an increase over secondary ion yields from collisional processes of a factor of ~100.

In the example of the interaction of 2 keV/amu Th^{70+} ions with a SiO_2 target (100 nm thermal oxide on Si), we conclude that up to 25 secondary ions are emitted upon impact of the highly charged ion, assuming a 10% detection efficiency of our TOF-SIMS setup. Negative secondary ion spectra from thin SiO_2 films show series of SiO_2 clusters with masses up to 676 amu ($[SiO_2]_{11}O^-$). Positive secondary ion spectra are dominated by the atomic ions of the sample compound. Once a threshold incident ion charge for the onset of Coulomb explosions is exceeded, yield ratios of positive atomic secondary ions appear to be constant at the stoichiometric value of 1.98 (+/- 0.05) for thermal SiO_2 films.

The systematics of highly charged ion induced electronic sputtering and desorption processes will be described with a focus on the contribution these new breed of primary ions can make as analytical tools in SIMS, namely the strong increase of useful yields and the promise of quantitative - "Matrix Effect" free - secondary ion mass spectrometry.

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[3] J. McDonald et al, PRL 68, 2297 (1992), F. Aumayr et al, PRL 71, 12 (1993) 1943
[4] I. S. Bitenskii et al, Sov. Phys. Tech. Phys. 24 (5), May 1979

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